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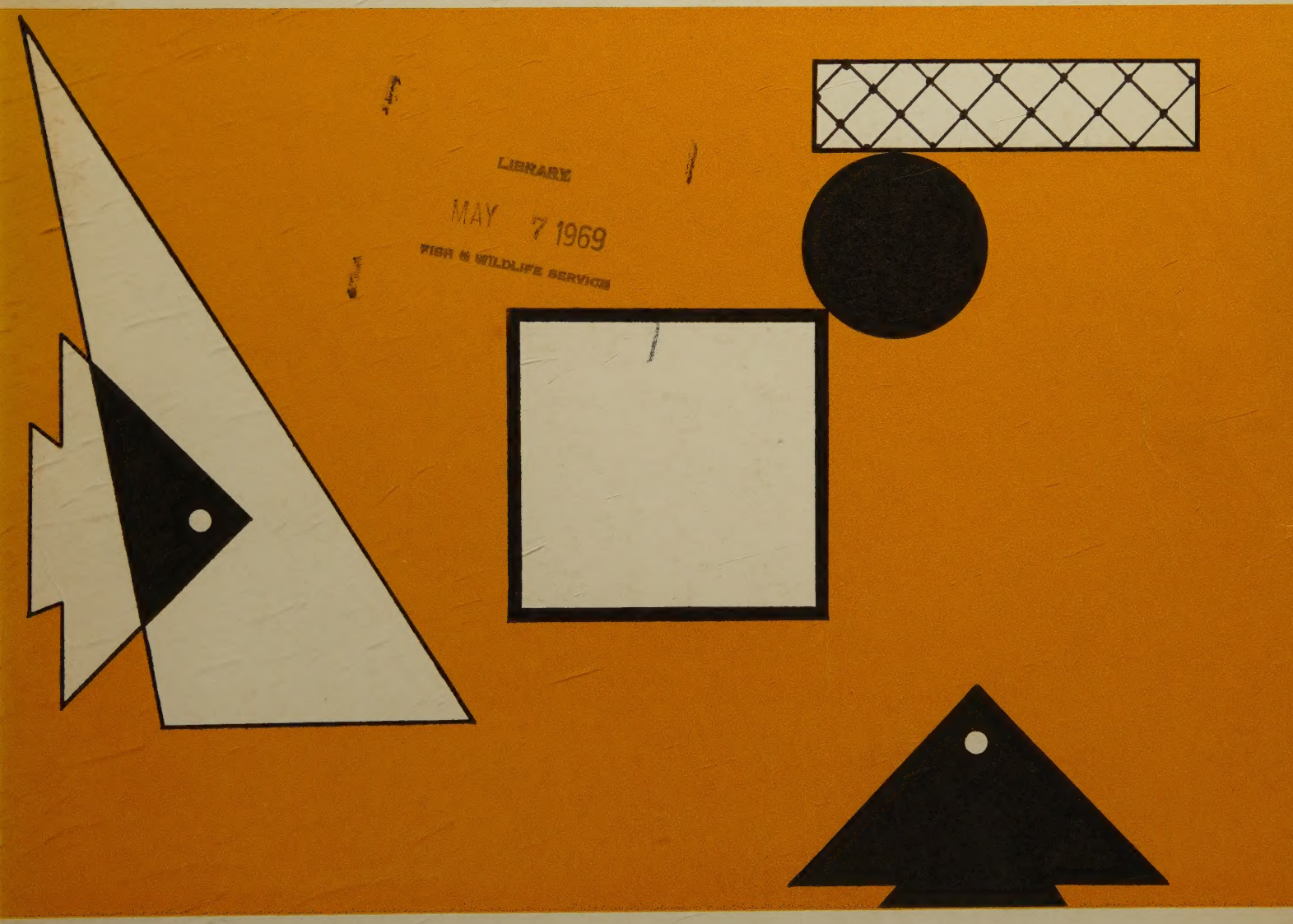
PROCEEDINGS OF THE CONFERENCE ON FISH BEHAVIOUR IN RELATION TO FISHING TECHNIQUES AND TACTICS

Bergen, Norway, 19-27 October 1967



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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1968

PROCEEDINGS OF THE CONFERENCE ON FISH BEHAVIOUR IN RELATION TO FISHING TECHNIQUES AND TACTICS

Bergen, Norway, 19-27 October 1967

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VOLUME I - REPORT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS REPORT

This is the first of the Proceedings of the Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics held in Bergen, Norway, 19-27 October 1967, and it contains the general report of the Conference. The subsequent volumes of the Proceedings will contain the Review Papers and Experience Papers contributed to the Conference. Information papers circulated as background material will be excluded. Dr. E. Clark (U.S.A.) helped in editing this volume of the Proceedings.

The views expressed in the Proceedings are those of the contributors and participants and not necessarily those of the Food and Agriculture Organization of the United Nations.

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1. INTRODUCTION

It is increasingly recognized that the capability of man to utilize the immense potential of the living resources of the oceans depends largely on his ability to relate the behaviour of aquatic organisms to the physical laws governing the instruments of search and capture. The lack of precise information on fish behaviour limits the design of well-adjusted gear. Newly designed instruments of search and capture are now being used as research tools to find out more about animal behaviour in the sea environment. This newly acquired knowledge is then used to further the design of the tools and to improve the tactics of fishing. The technological job of designing tools that will give meaningful answers goes hand in hand with the scientific job of interpreting results and developing theory.

Member Nations, realizing the importance of these problems, agreed at the Thirteenth Conference of the Food and Agriculture Organization (FAO) to hold a Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics. The Government of Norway graciously offered to act as host and the Directorate of Fisheries under the Ministry of Fisheries undertook to help in organizing the arrangements for the Conference which was held in the Hotel Norge, Bergen, from 19 to 27 October 1967. It brought together 128 participants from 35 countries, mainly research workers engaged in studies pertinent to the subject of the Conference. The Conference had an interdisciplinary character, in that specialists in various fields participated, e.g. fishery biology, fishing techniques, basic fish behaviour studies, oceanography and engineering.

2. BACKGROUND

Several countries have, in recent years, been intensifying research efforts to improve scientific understanding of fish behaviour with a view to improving fishing techniques and tactics. During the FAO Fishing Gear Congresses in 1957 and 1963 much attention was devoted to this topic and recognition was made of the importance of expanding research in the field of fish behaviour in relation to fishing. Similar conclusions were drawn during the Symposium on Fish Behaviour held in 1958 under the auspices of the Indo-Pacific Fisheries Council (IPFC). In view of the increasing interest in this subject and its importance for better study and exploitation of aquatic resources, the FAO Advisory Committee on Marine Resources Research (ACMRR), at its Third Session in March 1965, discussed a proposal for a conference and agreed that such a meeting of experts should be sponsored by FAO. The convening of a Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics was approved by the Thirteenth FAO Conference, in November-December 1965. Responsibility for the preparation of the Conference was taken jointly by the Marine Biology and Environment Branch and the Fishing Operations Branch within the then newly formed Fishery Resources and Exploitation Division of the FAO Department of Fisheries. The scope and planning of the proposed Conference were reviewed by the International Council for the Exploration of the Sea (ICES) in October 1965 and 1966, and by the International Commission for the Northwest Atlantic Fisheries (ICNAF) in May 1966.

At this point it is worthwhile restating the objectives and scope of the Conference as set out in its prospectus so that on reading the report on the Conference and its proceedings one may assess how far its objectives were achieved.

3. OBJECTIVES AND SCOPE

The objectives of this Conference were to review systematically the existing knowledge on fish behaviour in relation to fishing gear and to fishing operations in general and to stimulate further studies in this field by creating the opportunity for exchange of information between workers in various professions and disciplines. While no strict limitations on subject or approach were intended, contributions to the Conference were expected to be directed primarily towards those actively engaged in fishery research and the development of fishing methods.

One of the objectives was to evaluate known facts and prevailing theories on the ways fish react to their environment, to each other and when confronted with various means of capture. The complexity of the problems involved required consultation among workers engaged in "applied" or "mission oriented" research in gear technology and fishery biology and those pursuing more fundamental "discipline oriented" studies.

With these objectives in mind, it was intended that the Conference would:

(a) summarize the present knowledge of the relationship between fish behaviour and fishing techniques;

(b) identify gaps in our knowledge and the most urgent needs for future studies;

(c) facilitate exchange of research experience and ideas between specialists engaged in various fields of science and technology;

(d) advance the possible application of already accumulated scientific data to the development of more efficient fishing methods;

(e) critically review the prevailing methods and devices used in investigations of fish behaviour in relation to systems of capture;

(f) encourage further national action by dissemination of information and making recommendations for working schemes based on the collective experience of the world's leading scientists and technologists in this field.

4. PREPARATION AND ORGANIZATION OF WORK

To facilitate preparations for the Conference, 19 experts were invited in May 1966 to form a Consultative Group to assist FAO in programming and organizing it and in evaluating papers submitted (see Appendix 2). A draft prospectus was issued and distributed for comments to the Consultative Group and other experts and a revised version was issued in February 1968.

The Consultative Group could not meet as a whole but by correspondence and discussions with those who passed through Rome, or whom the Joint Secretaries met on their travels, valuable consultations took place on conducting the Conference. As a result of these and a meeting on 15 September 1968 in Headquarters, attended by Dr. D.L. Alverson, Mr. J.H.S. Blaxter, Mr. C. Fuss and Dr. T. Kuroki, experts were selected for convenors and rapporteurs.

Members of the Consultative Group attending the Conference and convenors met one day before the opening of the Conference to finalize the programme and plan of work.

Well in advance of the Conference a provisional list of experts in the subject matter of the Conference was drawn up and circulated for comments and corrections. A special questionnaire was issued and from the information returned a first revision of the list of experts was issued on 29 September as an Information Paper FR:FB/67/Inf.2.

Conference papers were:

(a) 12 Review Papers prepared by invitation to give a detailed summary of the main subjects, supplemented by bibliographic references;

(b) 56 Experience Papers prepared by professional workers with results of research and relevant observations;

(c) Information Papers with general information on the preparation and programme, including the prospectus and Lists of Experts.

Review and Experience Papers presented in provisional form to the Conference have been rechecked and will be published in final form in additional volumes of the Proceedings.

Review and Experience Papers were discussed at the plenary sessions. Most authors presented papers verbally. Other papers were introduced by the convenor/rapporteur or a participant acquainted with the work. Following this and discussions in the last two days of the Conference, suggestions were made for areas of further study and three recommendations were adopted (see Sections 8 and 9).

The 68 Conference papers were arranged in five sessions. The Chairman presided over all sessions with a convenor and a rapporteur. The Chairman's role was to initiate and develop policies during the Conference, chair the formal Conference meetings, and lead the Consultative Group meetings. Each convenor conducted one session and took part in meetings of the Consultative Group held during the Conference. He introduced the subject of his session and the speakers, initiated and supervised the discussions and prepared, together with the rapporteur, a summary of the proceedings of his session.

The five reports prepared by the convenors and rapporteurs and six reports of ad hoc working parties are included in this volume of the proceedings.

The Norwegian fishery research vessel Johan Hjort and U.S.S.R. research vessel Fritjof Nansen were in Bergen during the Conference and, by courtesy of the captains, Conference participants inspected the ships and their scientific equipment.

5. OPENING SESSION

Dr. S.J. Holt, Director of the Fishery Resources and Exploitation Division of FAO, opened the Conference. Mr. K. Sunnanaa, Director-General of the Norwegian Directorate of Fisheries and Honorary President of the Conference, delivered an opening address on the importance of fish behaviour studies in relation to fisheries in general and especially to the development of Norwegian fisheries. Mr. J. Morken, Deputy Mayor of Bergen, welcomed participants on behalf of the city. Dr. Holt greeted the guests and participants on behalf of the Director-General of FAO and the Assistant Director-General (Fisheries), delineated the objectives of the Conference and reviewed some of the activities of the FAO Department of Fisheries. He explained the proceedings to be followed at the Conference and turned over the chairmanship to Dr. D.L. Alverson. He also introduced Mr. Ole Rieck, Acting Governor (Fylkesmann) of the Counties of Bergen and Hordaland; Mr. J.H. Bertnes representing the Ministry of Fisheries; and the two Vice-Chairmen, Mr. I.V. Nikonorov of the U.S.S.R. and Dr. T. Sasaki of Japan. Dr. A. Ben-Tuvia, in the opening address on behalf of the Joint Scientific Secretaries, explained the technical arrangements of the Conference.

6. REPORTS OF THE TECHNICAL SESSIONS

6.1 Field observations on fish behaviour in important fisheries

Convenor: J.H.S. Blaxter

Rapporteur: E.L. Nakamura; S. Olsen

(a) Pelagic fishes
Documentation*: R/2, E/3, E/24, E/27, (E/8), (E/29), (E/30)

(b) Ground fishes
Documentation*: R/7, R/10, E/11, E/34, (E/49)

Four papers were presented under agenda item 1(a) (pelagic fishes). F. Devold reviewed the behaviour of the Norwegian tribe of Atlanto-Scandian herring. Movements during various seasons were described, particularly feeding aggregations, spawning migration toward shores and behaviour in the spawning area. The paper by S. Zupanovic on sardine behaviour in the natural environment discussed diurnal vertical migration in relation to light, food, temperature and the thermocline, and its effect on catches. O. Dragesund and L.S. Midttun, referring to a research survey of West African waters, gave some results on acoustic fish detection, abundance and identification of echo traces, hydrography and plankton sampling. E.L. Nakamura reviewed field observations on tuna behaviour, knowledge of tuna behaviour possessed by tuna fishermen and how they exploit this knowledge.

Under agenda item 1(b) (ground fishes) there were four contributions. G.Saetersdal reviewed available information on the behaviour of commercially important gadoid species. He noted the vast number of observations on fish behaviour made by fishermen themselves but generally inaccessible to the literature survey. He reviewed the fairly extensive literature on various patterns of general behaviour in these species, e.g. environmental characteristics affecting the distribution of the fish, seasonal and diurnal vertical migrations, schooling, feeding and spawning. Considerably less was known about the reactions to fishing gear. Recently some publications have appeared on the response of these fish to visual, chemical and mechanical stimuli and on lateral line perception.

Two papers, by D.L. Alverson and M.O. Nelson, described distribution, relative abundance and behaviour of the North Pacific hake. A fishing system designed to function effectively in response to the diurnal behaviour patterns had been developed. The paper by S.J. de Groot reviewed the extensive literature available on behaviour in flatfish, emphasizing differences in feeding of the different families and how these affect various aspects of behaviour. Information on locomotion, spawning behaviour and reactions to chemical, optical, hydrostatic, sonic and temperature stimuli was reviewed.

Discussions began with an attempt to formulate a working definition of "school". Two criteria were listed: biosocial mutual attraction and parallel orientation. Several examples of disruption and creation of parallel orientation were mentioned, such as the loss of parallel orientation during feeding and its creation by throwing food into the water or by herding flatfishes with a trawl. The question of whether these examples should be considered a school arose. A precise definition of schooling seemed at first to be of more interest to the sensory physiologist or ethologist, anxious to clarify the stimuli holding the fish together. For the fishery biologist the most important factor was that the fish were grouped, facilitating capture. Since an agreement could not be reached on definition, it was considered necessary to define the term "school" before using it.

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*Serial numbers of Review and Experience Papers of primary interest in each agenda item are quoted without brackets, those of secondary interest in brackets.

The search for food near the surface at dusk and dawn does not fully explain the mechanism of vertical migrations. Feeding could also take place at considerable depths by day. If feeding was essentially at dusk and dawn, why should not fish remain at the surface by day unless predators were more abundant here than elsewhere? Exceptions to the usual pattern were given, such as the vertical movement of Atlanto-Scandian herring into surface waters at night during the winter, even without food there, and reverse migrations of some fishes in the Antarctic which came to the surface in the daytime to feed and moved down at night. Both fishes and zooplankton migrate to obtain food at least risk of predation. Vertical migration in relation to oxygen requirements and buoyancy was also briefly discussed. The importance of vertical distributions during various times of the day was related to fishing methods, e.g. bottom trawls, midwater trawls or purse seines. The shape of the net mouth was discussed in relation to shape, size and vertical position of fish aggregations. Fish activity and sleep was considered. Examples of labrid fish sleeping on the bottom of aquaria by night and of sleeping cod and haddock in the Barents Sea were given. Instances were reported when catching Atlanto-Scandian herring was only possible between 0200 and 0400 hours with midwater trawls. Increase in sound production by haddock during dawn and dusk and a decrease during day and night was possible evidence of variations in activity levels. The possible effect of fishing on the distribution and size of fish concentrations, leading, for instance, to the break-up of large schools or aggregations, might result in severe losses of efficiency. To some extent the physiological state of the fish was involved. For instance, Arctic cod were most easily purse-seined before spawning. The type of food being eaten by the fish was also important. For example, the reaction of cealfish to purse seiners varied with the food organisms exploited by the fish.

Increases of catches on certain grounds could show a progressive improvement. When longlining for Greenland halibut the Norwegians found the initial catches sometimes low. The discarding of fish offal was believed to have attracted more fish to these grounds, for later the catches began to increase. Changes in the persistence of hake schools after two years of exploitation and the greater frequency of smaller schools in depleted stocks of herring were also mentioned. Reductions of school size and abundance of herring during one day of trawling in the southern North Sea was illustrated with examples from echo soundings.

The role of weather in changing the availability of fish was briefly examined. During heavy rains and storms in June and July in southern India the bottom sediments in shallow waters were so stirred that a trawl could not be operated. During this period prawns were found at the surface. In Sakhalin, after a change of wind from the prevailing direction, herring come to the surface and become vulnerable to purse seines. The experience of divers suggested that in deeper water the weather, apart from restricted effects on turbidity and light patterns, might have more prolonged effects on the hydrography of an area. This merited further study.

Many examples of sexual differences in behaviour and their effects on fishing tactics were cited. The sexes of the tanner crab in the eastern Pacific remain separate for about nine months, the large males in shallower water and the smaller females in the deeper parts of their bathymetric range. Thus, during certain months, larger male crabs could be selectively exploited. The sexes of North Sea plaice move from their spawning grounds differentially, affecting size distributions at different times of year since the female is larger. In a Mediterranean species of fish, females were found in a higher layer of water than males, so trawls could catch disproportionate numbers of each sex depending on the depth of fishing. Male bluefin tuna can be harpooned along the Canadian Atlantic coast, because they bask at the surface, while females are caught only by surface longlining. Examples of differences in response to stimuli during various stages of sexual development were also cited.

6.2 Methods and techniques for studying fish behaviour in the natural environment

Convenor: D.H. Cushing

Rapporteurs: C.C. Hemmings (section a); L.S. Midttun (section b); J.J. Foster (section c)

(a) Direct and indirect underwater observations

Documentation: R/9, E/2, E/45, E/55, (E/25), (E/35)

The paper by T. Sasaki on this subject was presented by D.H. Cushing. It described current Japanese work in diving and submersible methods and indirect methods such as underwater TV. Some Japanese diving was shown in a film later.

S.B. Saila showed slides of the Westinghouse submersible Deepstar 4,000 in Cessair Canyon near St. George's Bank in the Gulf of Maine, U.S.A. Its maximum operating depth is 1,300 m (4,000 ft) but the slides were taken at about 300 m and showed both invertebrates and fish, and emphasized the importance of erosion as an ecological factor. Visibility allowed observations up to 10 m. Future work will involve quantitative surveys. Whether infra-red could be used for unobtrusive observation was asked but apparently the absorption was too high for this. It was commented that the slow speed of the vehicle limits the prospects of its use in fishery studies.

The paper by W.L. High, presented by R.B. Thompson, described scuba diving as useful for direct observation of fish reactions to a trawl in action.

V.N. Martyshevsky and V.K. Karetkov described the towed bathyplane Atlant, a one-man vessel allowing observation of various parts of a trawl in action. No observation has been made of pelagic trawls. It was assumed that the lateral line was involved in avoidance of mud clouds by fish, which escaped in different directions.

A description was given by O.N. Kiselev of direct observation from the Hydrostat, a one-man observation chamber lowered to the bottom in depths down to 200 m in the Barents Sea. With the help of lights and cameras, observations and recordings were made of cod, haddock and other species, some in a low state of activity.

E.L. Nakamura showed a film of a surface observation chamber attached to a raft used for the study of pelagic fish and the attraction of fish to floating objects. It had the advantages of being simple, inexpensive, and efficient in its operation.

(b) Sonic devices

Documentation: R/4, R/5, E/7, E/37, E/46, (E/12)

H. Mohr's paper raised the possibility that the CTFM sonar could be used to identify fish. It was pointed out that FM-sonar has been used for detailed studies of the distribution of tuna but there are still difficulties with the identification of the target. Controlled experiments on cod and saithe have shown that the target strength varies not only with the size of the fish but also with the orientation of the fish relative to the acoustic axis of the beam. The latter variance is different for cod and saithe and might be utilised for identification.

Discussing D.H. Cushing's paper, information has been given on scattering layer studies made on board RRS Discovery using three echo sounders with different frequencies. The recordings of a scattering layer differed markedly on the different sounders. Target strength of fish changes with frequency but not much - an increase of about 12 db for an increase of a factor of 14 in frequency. A possibility was suggested of distinguishing muddy bottom by measuring the duration of the bottom trace in time. The use of very high frequency for recording targets in the bottom was contemplated. Prawns could perhaps be recorded by night when they rise above the bottom. How close to the

bottom a fish can be distinguished depends on the pulse length and the beam angle because of the "dead field" in the beam near the bottom. Sophisticated research instruments are being designed to cope with these difficulties but commercial equipment available is far from satisfactory for observing fish close to the bottom, a point to be carefully considered when using such equipment. It was suggested that the importance of calibration and different methods of effecting it should be a topic of discussion for a working group.

In the discussion on A.G. Poddubny's paper, it was suggested that the reaction to the wire could be visual, since no control observations had been made without voltage on the wire.

D.H. Cushing briefly explained two new types of acoustic gear recently tried in England. The "gloria" transducer constructed at the National Institute of Oceanography is a sonar directed sideways at a low tilt angle. The beam is a fan with a horizontal spread of about 2° with a wide vertical beam. The other was the "acoustic arch" attached to the headline of a trawl. The gear operates on 100 kHz and can be used for detailed studies of the fish behaviour in relation to the trawl.

Sonic gear is now widely used in fish behaviour studies, including several types of sonar, echo sounders, netsounders and sector scanners. The last which has recently come into use, seems to be particularly promising equipment for detailed studies of this kind. However, many technical and operational problems must be solved before a full utilisation of such gear can be obtained.

The problem of target identification is probably the most important because acoustic identification is not yet possible. Therefore sonic gear has to be used in combination with equipment which can identify fish (i.e. underwater cameras mounted on the fishing gear) and also count the targets.

It is stressed that all sonic devices applied to fish behaviour studies should be calibrated. The methods are known but not well documented. With an uncalibrated device, most of the information is of no use.

The attention of scientists working in the field of fish behaviour should be drawn to the forthcoming FAO publication "Training Manual on Acoustic Methods for Population Estimation" where methods of calibration of sonic devices will be fully described.

(c) Comparative fishing
Documentation: R/6, E/33, E/43, (E/14)

The Convenor pointed out that comparative fishing experiments could not provide direct evidence on fish behaviour but, in the absence of more direct measuring techniques, a useful tool for highlighting the essential areas in behaviour should be pursued. Such experiments also indicate the relative effectiveness of different trawls and are useful in studying specific variations in other fishing techniques. Emphasis should be placed on the need for adequate experimental models and rigorous statistical analysis, particularly as in many applications of comparative fishing it is not possible to study the variations of just one parameter at a time.

A.R. Margetts examined the value of experimental fishing and comparative fishing in particular and suggested that while there were serious limitations they could be of considerable value.

The paper of J.S.H. Yuen (presented by E.L. Nakamura) described comparisons of catch rates of skipjack tuna when the bait was varied and when water sprays were or were not used. The difficulty of comparing results of tests, when different "frenzy states" so much influence catching rate, was discussed. The author had used different schools of fish and this work was particularly relevant when considering low "frenzy states".

The paper of J.P. Bridger (presented by A.R. Margetts) described a series of comparative fishing experiments on demersal fish and a hypothesis to describe the results was incorporated.

J.J. Foster explained how the comparative fishing results described in J.P.Bridger's paper, combined with other direct evidence on the reaction of fish to gear or gear components, could be utilised in formulating certain equations. These equations not only assisted in understanding the data but also pinpointed those areas where high or low precision of future measurement were necessary. Some comparisons of the effect of propeller noise in relation to purse seining were discussed and it was reported that considerable noise reduction could be achieved by propeller modifications. The author had emphasized that in comparative fishing with trawls it was impossible to isolate one parameter for testing because the various parameters were interdependent. This was not fully recognized by some participants. The use of a small control gear towed from the same vessel was suggested but the possibilities of interference reduced its value. Possible reasons for the vast improvement achieved by the introduction of bridles to trawl gear was discussed.

6.3 Experimental studies of fish reactions to physical and biological stimuli, both in the natural and in a controlled environment

Convenor: F.R. Harden Jones

Rapporteur: S.B. Saila

(a) Non-biological stimuli
Documentation: R/11, E/1, E/4, E/8, E/15, E/16, E/18, E/19, E/20, E/21, E/22, E/28, E/44, E/48, E/50, (R/10), (E/26), (E/33), (E/39), (E/42), (E/46)

(b) Biological stimuli
Documentation: E/19, E/17, (R/11), (E/11), (E/18), (E/26), (E/33), (E/34), (E/48)

The Convenor pointed out that one of the commonly utilized response variable of fishes is the locomotor response (swimming speed). Locomotion may involve not only velocity but acceleration, frequency of turning, angle of turning, step length before turning and combinations of these. Swimming speed (velocity) is therefore only one aspect of locomotion. The terms "kineses" and "taxes" have become well accepted in behavioural literature. For our purpose we may consider kineses to involve undirected locomotor activity due to variations in stimulus intensity. These are expressed as changes in velocity, frequency of turns and angles of turning between stop lengths. Overall movement may be expressed as a mean vector with directional and distance components. Taxes or directed movements are divided into klinotaxes involving a sequential comparison of intensities; tropotaxes, the simultaneous comparison of the intensity of stimulation of bilateral receptors, and telotaxes, direct orientation with no comparisons when the animal localizes the sound and movement as toward or away from the source. The light compass reaction is a special case of telotaxis where movement is at a fixed or varying (azimuth compensated) angle to the horizontal projection of the line between the animal and the light source.

With reference to biological and non-biological stimuli and responses, there are stimuli with directional properties which include light, gravity, water movements, mechanical displacements and electrical fields. Those without directional properties include chemical and temperature stimuli. While directional responses can be made in response to directional stimuli, we may only expect kineses and klinotaxes (sequential comparisons of intensity) to chemical and temperature stimuli unless the gradient is steep enough to be detected across the width or length of the body when a tropotaxis (simultaneous comparison of intensities) seems possible. In practice we are often

interested in the threshold response, i.e. the minimum stimulus for a response. This can be measured by electro-physiological techniques, training and response observations and by observation alone.

The question was discussed as to whether sufficient care was being given to the real nature of the stimulus perceived by the fish. In light fishing there are problems of wavelength, intensity and angular distribution. In the response to thermoclines, particularly evident in light fishing, there is the problem of deciding to which stimulus the fish responds. The rate of temperature change generated by the thermocline gradient and the swimming speed of the fish may well be important. There were suggestions that the rate of change of light intensity might be an important factor in the response of fish to artificial light, diurnal changes of intensity and angular radiance distributions. With regard to the response as measured by a change in swimming speed, it may be desirable to use vector notation when describing locomotory behaviour.

In considering the fish's reaction to sounds, the interaction between swim bladder, labyrinth and lateral line in pressure and displacement reception is becoming clear. There is a need for more observation on behaviour in the field by direct observation (diving and observation chamber) and the use of sophisticated sonar techniques.

Convenor: G. Sundnes

Rapporteur: E. Shaw

(c) Learning and conditioning
Documentation: (E/19), (E/26), (E/48)

(d) Fish locomotion
Documentation: R/3, (E/6), (E/17), (E/26), (E/35), (E/43), (E/48)

This session was concerned with three main topics: (i) early development and learning, (ii) schooling behaviour and (iii) locomotion in fish.

Among plaice larvae some become predacious and attack prey whereas others withdraw from the prey. This brought about a discussion that behaviour is not entirely instinctive and that the experience and learning gained through development from larva to adult is an important aspect of behaviour of the adult. R. Thompson described experiments with juvenile salmon which were conditioned, through shock, to avoid models of predators. Trained and untrained fish were released and subsequently recaptured five miles downstream. The survival rate of trained fish was 10% higher than that of untrained fish.

E. Shaw's paper on schooling behaviour surveyed the definitions of schools, sensory systems, communication and the psychology of schools. She brought out the importance of finding out what stimulates the formation and maintenance of schools. This kind of knowledge may be useful in the design of fishing gear, particularly if natural biological reactions can be utilized. Tagging experiments in the Barents Sea were discussed which showed that haddock and cod form stable schools which may remain together for as long as two years and continue through the migratory phases.

D.V. Radakov's paper stressed the importance of knowing how stimuli spread through a school, a factor critically pertinent in catching schooling fish. He demonstrated that a disturbance may disrupt only one part of a school, 2 to 3 m in size, creating disorientation at one small area such as the formation of a dent in the edge or an opening in the centre. However, as this disturbance passes through the school, it becomes attenuated and is finally dissipated. Waves of movement of reactivity and reorientations must be studied in greater detail. According to Radakov's observations such waves travelled at 10 m/sec in a school of 2 to 3 m size.

During the discussion observations were mentioned on schools in the Red Sea where one small part of a school may be disrupted without a disruptive effect on the remaining fish. Sensory systems seem to be important in maintaining schools during darkness.

J. Magnusson's paper on swimming activity in Euthynnus affinis was presented by E.L. Nakamura. Responsiveness to food (measured by increased swimming speed) was greater in daylight than at night in fish that were deprived of food. However, swimming speed, in general, shows no diel periodicity. Swimming speed is evidently regulated by the need to maintain hydrostatic equilibrium and gill ventilation.

J.H.S. Blaxter covered swimming speeds in a variety of fish and pointed out certain criteria used in these studies must be evaluated, such as performance of captive fish, exercised fish and the water velocities involved in the tests. He separated swimming speeds into two major categories, burst speed and cruising speed. Red muscle is utilized in cruising, white muscle for burst swimming. Burst speeds usually cannot be maintained for more than 5 sec and the fish swims a distance of 10 body lengths/sec. Cruising speeds are 2 to 3 body lengths/sec generally, although clupeoids are known to swim 4 body lengths/sec. In discussion on the lactic acid production, J.H.S. Blaxter reported that it may require up to 24 hours for a fish to recover its normal oxygen level and to reduce the lactic acid concentration after a single burst of 5 sec duration.

During the discussion the following questions were raised:

(i) Is a time base a good measure for locomotory studies?

(ii) Does schooling give fish opportunity to swim faster with less energy?

(iii) How much does lactic acid concentration influence the white muscle?

(iv) Which method should be recommended for locomotory studies?

Cruising speed is the maximum that can be maintained without building up an oxygen deficiency. The interaction between white and red muscle is difficult to assess.

One participant had observed capelin (17 cm long) maintain a speed of 20 to 25 miles/day or 0.5 m/sec, three times body length. A school of capelin moved 16 miles when fished over a 10-hour period. The fish were swimming mostly against the current. F.W.H. Beamish reported that a fish swimming at 3 body length/sec did not accumulate an appreciative level of lactic acid and after strenuous exercise swimming performance is impaired. It has also been asked if diminished performance after a second burst speed meant that it is of less magnitude or the same magnitude but of shorter duration.

Merely stating swimming speed in terms of m/sec was inadequate and direction of movement must also be included. Temperature is also a component. Discussion can be summed up as follows: 1) Burst speed is more likely to be temperature independent than cruising speed. There are no experiments which conclusively show that speeds are or are not directly correlated with temperature. 2) Research into the hydrodynamics of swimming is still at a preliminary stage because it is not possible to extrapolate from towed bodies and fish models to the living, actively swimming fish. 3) The known data on fish speeds is equivocal since too many variables are unknown. Approximations indicate that a number of species e.g. cod, herring, swim 1 m/sec. 4) Biological factors should be examined, such as season, diel rhythms, vegetative state, reproductive state. 5) During escape reactions fish tend to swim in a straight line and this reaction may be useful for accurate measurements of swimming speed.

This section also dealt with pertinent biological activities such as schooling behaviour, locomotion, and development. If some factors of schooling behaviour such as the mechanisms concerned with fish-to-fish attraction and the manner and speed with which a stimulus is transmitted through a school is better understood, there is the potential of designing gear which can maximise the attraction and communication phenomena.

The locomotory studies indicate strongly that we do not have any clear cut methodology established for determining swimming speed in fishes. A differentiation for study must be made between burst and cruising speeds and many parameters must be considered when testing fish for locomotor ability. The parameters include: 1) condition of the fish, e.g. exercised or not, biological condition (hungry, well-fed, reproductive state, etc.); 2) location of tests, e.g. in natural environments, laboratory or other capture conditions; 3) hydrodynamic aspects, e.g. flow patterns with water and around the fish velocities; 4) temperature effects; 5) components of locomotion, e.g. cruising and burst speeds and direction of movement of the fish.

The concensus was that many values of speed measurements are not comparative because of the different techniques used. Actual values are yet to be determined and should be given in a standardized unit, such as metres per second with reference to body length. Accurate knowledge of swimming speeds will be of enormous value to designers of fishing gear.

Developmental studies illustrate the role of experience during early life and the need to pay greater attention to developmental stages. One experiment was cited in which juveniles, trained by shock to avoid a predator, survived in greater numbers.

6.4 Experimental studies of fish reactions to moving and fixed objects in order to clarify reactions to fishing gear

Convener: C. Nedelec

Rapporteurs: F.W.H. Beamish; A.R. Margetts

Documentation: R/12, E/5, E/6, E/12, E/14, E/23, E/25, E/29, E/30, E/31, E/32, E/35, E/36, E/38, E/39, E/40, E/41, E/42, (R/10), (E/2), (E/28), (E/45), (E/46), (E/47), (E/49), (E/50)

The papers of B.B. Parrish and C.C. Hemmings concerning reaction distance and learning were discussed. The usual reaction of fish to the advancing trawl will be a burst of speed, building up quickly and followed by a reduction of speed. Fish can be taught to react to a simple stimulus in a laboratory after about three trials and there are likelihoods of fish encountering fishing gear in the open ocean frequently enough in a short period of time to provide learning possibility. The trawl, however, is such a complex of stimuli that a fish is most unlikely to repeatedly encounter the same part of the gear representing the same stimulus, and learn by trial and error how to avoid capture. It is also unlikely because the first punishment is usually capture. Repeated escape through meshes may encourage learning and colour pattern display may communicate warning between fish, although there was no evidence of reaction distance change to indicate learning in tanks.

Papers of M. Nomura and T. Shiokawa on gillnets and trapnets were reviewed. It was pointed out in discussion on the leader of traps that fish often avoid meshes large enough to enable them to pass through and this experience has led to the trial of very large meshes in the wings of trawls.

Papers by P. Strom, M. Inoue, and T. Ayodhyoa, C. Nedelec and M. Portier on purse seining were discussed. Some species of tuna and porpoises seem to be influenced by sonar transmission. There was no confirmation that chemical repellent is useful for

preventing escape of fish just before pursing is completed but green dye repellent is used to discourage the fish from crossing the area beneath the ship. The reason for the difference in shape and net hanging between European herring, American salmon and tuna purse seines was discussed. Hanging rate, relative rope lengths, net shape and weighting are all linked in their effect on sinking rate. The use of knotless netting could influence the effect of hanging rate on sinking speed.

The papers of C.J. Chapman and A.D. Hawkins, S. Zupanovic, J.J. Zijlstra, C.C. Hemmings and F.W.H. Beamish dealt with bottom trawling. In the discussion it was suggested to record trawl noises and use the recording in controlled experiments but it was found difficult to separate the pure "trawl noises" from others. Ship and trawl noises build up gradually to a maximum from zero over several minutes, allowing ample time for the fish to become used to it. Action of trawl bridles was interpreted. Attention was drawn to the statistical necessity for adequate replicate hauls which usually means sustained and costly work. The use of predator noise for herding was suggested.

J.H.S. Blaxter and B.B. Parrish presented further data on swimming orientation of fish in front of a trawl, which were contrary to their 1966 publication, in showing marked orientation in darkness beyond the light reaction threshold of the fish.

Papers of J.M. Christensen and G. Kurc on special trawls were reviewed. Of about 7,000 sole caught by the rake trawl, only about six or seven were injured. Attention was drawn to the possible danger to benthos communities on fishing grounds by damaging the sea bed with heavy trawls. The French selective shrimp trawl is used by some Dutch fishermen as it is efficient and prevents destruction of juvenile flat fish. In deep water at higher towing speed more shrimp become meshed and it is questionable whether this is due to different jumping response by the shrimp or to the water flow. Similar trawls are being tried out in other shrimp and prawn fisheries in West Africa and North America.

Papers of S. Okonski, A.R. Margetts and H. Mohr were concerned with pelagic trawling. Each referred to the minimum size of a pelagic trawl for catching fish. Large nets (25 x 28 m opening) and increasing speed bring new species into the catch, e.g. bonite. A change of speed of 1 cm/sec along the side of a fish could give a lateral line response, so that small speed and pressure changes may be significant. Divers have noticed that behind the belly of a trawl they can hang on and travel with little water resistance, whereas if they swim upward from there they meet a sheer between water moving with the trawl and stationary water.

6.5 Application of observations and experiments on fish behaviour in designing fishing gear and devising tactics

Convenor: D.L. Alverson
Rapporteur: E.J. de Boer

Documentation: R/1, R/8, E/9, E/13, E/26, E/51, (R/3), (E/4), (E/5), (E/11), (E/19), (E/20), (E/23), (E/31), (E/34), (E/36), (E/42), (E/43), (E/47), (E/48)

T. Kureki's paper described the problems related to fish motion (relation between spatial volume of the net bag and the spatial density of fish schools); visual sense and fishing gear (attracting or frightening fish by light); electro-fishing (required power) and thermal stimulation.

I.V. Nikonorov's paper described a system of guiding the Caspian kilka (Clupeonella spp.) by lights to the suction tube of the fish pump. In the Black Sea experiments were conducted with a new type of electro-fishing device which consists of two concentric spheres mounted on the suction tube. Between the spheres an electrical field is

created. Nikonorov quoted these production figures: in the Caspian Sea about 400 boats catch an average of 350,000 t of fish per year; in the Far East 100 boats catch 40,000 t per year and in the Black Sea a production of 10,000 t is obtained.

S.B. Saila's paper pointed out that practical aspects of decision-making in fisheries should be based on system analysis and especially Baye's rule might be helpful in this respect. The author explained his ideas on a block scheme of operation decisions for the haddock fishery and its possible use in the near future.

S. Okonski's paper (presented by A.R. Margetts) divides commercial fishes into three ecological groups according to the zones where they usually live: demersal, near-bottom and pelagic. Depending on this division, he gives requirements of shape and size of the nets to be used for better exploitation. The discussion pointed out that the influence of the type of bottom should be taken into consideration when fishing for demersal species.

A. von Brandt's paper reviewed the development of fishing methods in relation to fish behaviour (attracting, frightening, stupefying and inducing the fish to jump) and fish behaviour and gear construction (selection of material, size and shape of mesh, etc.). He pointed out that commercial fishing is the applied study of fish behaviour.

The paper of S.B. Saila and J.M. Flowers, presented by Saila, attempted to explain the theory of search applied to fishing activities. If other factors are constant, the probability of success in detecting fish increases with increased movement of the fish. Several participants felt this approach will be important in quite a number of fisheries in the future. It was pointed out during the discussion that the information on behaviour of fishes can be applied to alter the geometry of fishing gear or tactics so as to improve the probability of capturing those fishes which come under its influences. The probability of capture may also be improved by preventing responses that allow fish to escape harvest devices (e.g. electro-narcosis). Quantities of fish that come under the gear's influence might be increased by acoustical or other physical herding procedures and/or aggregating fish by chemical means.

7. REPORTS OF THE AD HOC WORKING PARTIES

7.1 Acoustic techniques for studying fish behaviour

Convenor: C.J. Chapman

Most commonly employed is the vertical sounding echo sounder but in general most biologists do not fully utilise this instrument. More valuable information could be obtained using calibrated, high-frequency, narrow-beam echo sounders where estimates of target strength could serve to estimate the size of fish and density of schools.

Sector scanners are in use at the Fisheries Laboratory, Lowestoft, and at the Marine Laboratory, Aberdeen. The Lowestoft equipment is currently being installed on Cliona. The Aberdeen sector scanner will be portable. It is hoped they will be widely used in fish behaviour studies. More thorough training in the use of conventional ranging sonar systems is needed and recommended so more use could be made of this type of equipment for fish behaviour studies.

A combination of passive listening and echo sounding may allow certain targets to be identified. More information is needed on the characteristics of fish sounds, according to size and species, and also on the incidence of sound production by fish in different phases of behaviour. High-power low-frequency echo sounds (i.e. less than 1.000 Hz), especially from the swimbladder, offer the possibility of identifying the size and species of pelagic fishes. More work is needed in this field, particularly with respect to different types of echo sources. In view of the importance of identifying fish schools, these two possible methods of passive listening and echo sounding are worthy of further study. In conclusion, cooperation between acoustic engineers (civil and military) and biologists in all countries was urged.

7.2 Use of submersibles in marine research and fisheries

Convenor: T.B.S. Gorman

The principal topics discussed are detailed below:

Types of submersible: (a) Self-propelled - range in size from one- and two-man units to large converted naval submarines. (b) Man-powered - can be towed by or suspended from a cable or can be controlled by ballast. Great variability in type, ranging from simple sledges to highly sophisticated deep-diving submersibles.

Application of submersibles in marine fishery research:

1. The use of submersibles as an integrated part of fishing fleet operations to: (a) Identify fish schools with respect to species by direct observation, following the detection of these schools by surface vessels. (b) Detect fish close to the bottom in deep water where normally bottom fish discrimination by echo sounders is very poor or unreliable. (c) Assess the suitability of the bottom for ground fishing operations.

The most suitable submersible for this application is a small vessel acting in conjunction with a mother ship. Large submarines tended to frighten fish away.

It was agreed that the owning and operating cost of a sophisticated submersible for the above purposes was impractical from the economic standpoint unless used in fleet operations.

The U.S.S.R. anticipates a 10 to 20% increase in catch rate by the use of submersibles.

2. Biological observations on ecology, general behaviour and distribution: Probably any type of submersible could be used for this purpose, depending on the nature of the work and the depth at which it is to be carried out. However, because of the effects of artificial light and possibly of the submersible itself, behaviour studies would have to be limited to the zone of natural light. Owning and operating less sophisticated submersibles for this application should be within the financial reach of most fisheries organizations.

3. Observations on gear performance and operation:
It was agreed that self-propelled submersibles are not suited to this application because of their limited speed and low manoeuvrability. Towed submersibles appear to be more practical. Limited visibility normally restricts their usage to shallow water and for this reason they can be comparatively simple and if they have to use artificial light they can obtain it quite simply by cable from the towing vessel. Owning and operating possibilities as for section 2.

4. Observations on fish behaviour in relation to fishing gear:
Essentially similar to 3 but, since artificial light can disrupt natural behaviour patterns, this in effect limits submersibles to the zone of natural light. Owning and operating possibilities as for section 3.

5. Assist fisheries management by stock assessment, particularly with respect to sedentary species, and by improvement, e.g. artificial reefs. Owning and operating possibilities as for section 2.

6. Measuring oceanographic parameters in situ:
Usually required to descend to great depth. Can be self-propelled, cable-controlled or manoeuvred up and down by ballast. Highly sophisticated and consequently expensive. A number of research institutions have developed and built this craft, while others have been built by private enterprise. The latter may be chartered for oceanographic work. Most submersibles could at times be adapted to undertake different types of investigations but it was more efficient in the long run to design for a specific application.

It was obvious from the discussion that the U.S.S.R. was the only country utilizing submersibles for the majority of the applications listed. The main reason for this was clearly the high cost of operation and also the generally low priority assigned to fisheries by most nations other than the U.S.S.R. It was also clear that submersibles have not been adequately documented whereas the literature on surface research craft is extensive. It appeared that only two submersibles have been or are being designed specifically for studying fish behaviour in relation to fishing and as yet only one of these is operational.

Therefore it was concluded that the working party:

(i) Should recommend that FAO produce a document containing full descriptions of all existing and planned submersibles related to problems in fisheries and oceanography similar to the existing document on research vessels.

(ii) Should also recommend that submersibles be included in the agenda of the FAO Technical Conference on Fishery Research Craft, May 1968.

7.3 Possibilities of herding, aggregating and controlling and/or restricting movements of fish for the purpose of improving harvests, relevant to: (a) extant gear, (b) developing futuristic extractive processes

Convenor: J.J. Foster

The working party first considered a wide range of factors which presently contribute to the extraction processes of fishing, together with some that are likely to play an important role in futuristic techniques. These factors were then rather arbitrarily reduced to those thought most relevant. Suggestions of possible lines of approach are not in "order of merit" and agreement on the inclusion of some items was not unanimous.

In trawling, stunning of fish concentrated in front of the net might be the most fruitful immediate development, while for other fishing techniques, extension and refinement of methods of concentrating fish by the use of light, combined with fish pump extraction, were most promising.

Extraction processes of the future may take unexpected forms which, among other aspects, will depend on the success of techniques utilizing behaviour of fish to artificially concentrate and select them, as well as on advanced engineering. Despite the obvious uncertainties, it was felt that close cooperation of workers in a wide variety of disciplines would not only bring forward realization of futuristic methods but also ensure that full and intelligent utilization finally occurs.

Conclusions

1. Methods of influencing the eddy-trail behind boards should be studied to improve their herding effect, especially to widen them to the extent that they coincide with the wings of the net.

2. Attention should be given to the application of optomotor visible and invisible panels to reduce escapement, e.g. the use of horizontal stripes.

3. Investigations should be made of the application of electrical, mechanical, acoustical and other means of disorientating or stunning herded fish to facilitate capture.

4. Studies should be made of the effect of increasing speed for the latter part of the trawling duration and simultaneous application of means of preventing escape, e.g. shedding of a chemical in the vicinity of the net.

5. New methods in the use of light to lead or drive fish into the capture area should be studied.

6. Studies are needed on artificially increasing the effect of bioluminescents to improve herding at low natural light intensities and by the use of luminescent material on the catching equipment.

7. Immediate attention should be paid by fishery biologists, oceanographers and engineers, in close cooperation, to problems which may arise with the possible introduction of automated futuristic fish harvesting techniques.

7.4 Experiments for behaviour studies and design of facilities

Convenor: J.M. Anderson

It seemed evident from the papers presented and the discussion they generated, that progress in understanding the relation of fish behaviour to fishing techniques and fishing gear has not been rapid. The contributing factors are several: One is the great expense required to conduct adequate field studies. Another has simply been "bad science". For example, in comparative fishing experiments, the assumption of equal availability has often not been verified, or sufficient replicates have not been made to define statistically the variance observed. Similarly, experiments involving modification of some dimension of nets or trawls usually have not recognized sufficiently that it is virtually impossible to vary one parameter without altering others.

An important factor responsible for the slow progress in this field has been the inability to recognize and cope adequately with the large number of variables present in any field study. Admittedly control of these variables would be impractical, if not impossible; but failure to monitor them is as much due to lack of knowledge as to what they all are (much less what are the biologically significant ones), as it is due to lack of instrumentation and techniques.

The working party decided against mapping out in detail possible experimental protocols. It does, however, offer the following suggestions for future work:

Species effects: knowledge of extent to which behaviour patterns and response to stimuli cut across phylogenetic boundaries would be useful, particularly to laboratory experimenters, to lessen pressure to use commercially important species in experiments.

Age effects: a general objective as above (younger, i.e. smaller, specimens lend themselves much better to controlled laboratory work, particularly if model-building of fishing gear is involved, than do the larger specimens of commercial importance).

Sensory perception: what are the sensory modalities to which fish can respond? A plea to (laboratory) experimenters to use more than one independent variable because not only is this the normal situation in nature but also because there is a dearth of information on the extent to which behaviour occurring in the presence of several sensory inputs is greater or less than the sum of the responses to the same stimuli when tested singly.

Swimming speeds: particular emphasis on effects of time (i.e. duration) and temperature.

Learning: extent to which behaviour is altered if previously exposed to fishing gear.

7.5 Short-term distribution patterns and fishing tactics and strategy

Convenor: A.P. Stickney

Under this general topic several rather diverse areas of discussion are possible. By tacit agreement the working party elected to discuss the subject with emphasis on methods for studying fish distribution and for making use of the data thus acquired. It was agreed that the subject title should include and perhaps stress the word "tactics". Within this framework the group accepted as a working guideline the following outline of problems for consideration:

(i) What are the most useful data to collect?

(ii) How may they be best collected?

(iii) How can they be handled?

(iv) How can relevant data be distributed and acted upon?

In connection with these questions, the distinction between pelagic and demersal fisheries should be recognized.

Several members of the working party reported that in their own countries practical answers to some of these problems had been reached. Clearly there are different limits to the observations that commercial vessels, scouting vessels and research vessels can make but some of the most pertinent items under question (i) appeared to be: (a) haul by haul or set by set, catch data reports; (b) diel changes in horizontal and vertical distribution of echo traces; (c) thermocline topography; (d) horizontal surface and bottom temperature distributions; (e) bottom topography and character; (f) plankton volumes; (g) meteorological data. Of somewhat less importance were: (h) dissolved O_2 (in areas where it is likely to be critical); (i) water colour and transparency; (j) size and age composition of catch; (k) stomach contents.

For all data, methods of collecting and recording should be standardized. Instrumentation seems adequate and underutilized at the present time, although such newer techniques as satellite positions fixing, weather mapping and infrared surface temperature mapping seem promising for some applications. Data could be collected from scout and research ships and relayed to the fishing fleet but most of the party felt that some important synoptic data could be collected by the fishing fleet itself to give comprehensive coverage of some of the most important items. Some members reported highly successful operations of this kind, with as many as 30 vessels cooperating and in one case the entire Japanese tuna longlining fleet of several hundred vessels. When engaging the cooperation of fishing captains, the scheme for collecting and recording data should be made as simple and straightforward as possible. The use of tagging for studying fish movements was also recommended.

Regarding the handling of data, the practice of discarding echo sound and sonar records was cited as an example where information on hand is not fully utilized. Ideally fathometer recordings should be copied or coded in a suitable way and transmitted by radio to other vessels and to a central data handling station. Suggestions for doing this ranged from the simple expedient of applying numerical or descriptive designations or trace sizes and types to more sophisticated techniques of electronically scanning the charts and transmitting them by radio where the fishery is in distant waters. In near-water fisheries simple methods of data collection had in some cases been successful in giving guidance to the fleet on short-term distribution factors. In a few countries data logging, long-distance radio communication and data processing and redistribution techniques are coming into use.

How best to go about the various procedures suggested above and to achieve the necessary coordination was not decided. To a great extent it would depend on the level of sophistication of the fishery. Nevertheless, some nations have already developed procedures which have been successful at their own level of sophistication and there seems to be no reason why similar programs of progressively increasing sophistication cannot be developed for any fishery where there is the willingness on the part of the fleet to cooperate.

The gain is likely to be not only in the development of more economic fishing in the short run but also to yield information of importance for the scientific understanding of fisheries and further as valuable training materials.

7.6 Sensory physiology - its possible contribution to behaviour studies and to design of fishing gear

Convenors: E. Shaw and C.C. Hemmings

Preliminary discussion emphasized the complexity, both of the biological system - the fish, and the typical stimulus situation - the gear, with which the fish was faced. The group endorsed the definition of three thresholds:

(a) Absolute threshold of the sensory system determined by electrophysiological techniques.

(b) The minimum behavioural threshold determined by conditioning techniques.

(c) The response threshold normally shown by the fish.

It was agreed that the third threshold was the most useful in fishery application but perhaps that which most varied with physiological state and age. It was felt that threshold determined for individual sensory modalities in the laboratory could not be strictly applied in the "multiple stimulus situation" existing in the natural environment. The notion of "reaction distance" was thought to be of limited value in this connection.

No firm conclusions were reached on the subject of the direction taken by fish when scared. Numerous examples exist of fish moving up or down which lacked consistency. It was suggested that controlled experiments at different times of the day might show a pattern of diurnal response, perhaps in relation to vertical migration.

This discussion led to one on light fields and variation of intensity with particular respect to the night light fishery. It was strongly felt that here was a field where cooperation between laboratory and field workers with carefully controlled experiments and monitoring of light intensity might give a more adequate answer to "why" and "how" fish are attracted to light.

A consideration of avoidance reactions by fish suggested that the so-called "protean behaviour", the zig-zag flight path shown by many prey species when avoiding predators, did not occur in the movement of fish away from trawls. By chance some stimuli generated by fishing gear might resemble natural ones and so lead to a different type of behavioural response. This was particularly the case with sounds, and this is being tried experimentally in some countries to guide fish by the playing of predator noise.

Consideration was given to the desirability or otherwise of trying to reproduce near - natural conditions in laboratory situations for fish behaviour work, as opposed to the more normal uniform controlled set-up. It was thought this might have some value, provided that the environmental conditions involved were continually recorded.

Schneirla's "approach - withdrawal" concept was discussed and considered useful in explaining the variability of response that always occurs. In this connection it was suggested that sensory physiologists should not attempt to specify actual values for response thresholds or reaction distances but instead to indicate ranges of probable values. The problem was discussed for some time in reverse, that is, what the sensory physiologist and behavioural biologist can learn from the reactions of fish to gear. The complexity of the multiple stimuli was the major problem here but it was suggested that it might be advantageous if large experimental apparatus could be used in the sea. This could provide exaggerated single stimuli to which the reactions of fish might be observed. The possible occurrence of responses to a pressure wave and associated displacement effects was here mentioned. The advantage of this kind of research would be that of bridging the gap between laboratory work and fishing gear. One further practical suggestion was that some thought might be given to passive gear where fish caught themselves or at least aggregated themselves. The possibility of trapping at floating rafts was considered.

It was emphasized that contact between gear technologists and academic students of fish behaviour must be continued. This requirement might be met by a journal in which work of mutual interest could be published. Apart from some suggestions mentioned above in the context in which they arose, the most valuable conclusion was that physiologists should suggest probable limits of reactions, rather than to specify actual values. The final conclusion of the group was that behaviour studies at a sensory physiological level have contributed little to gear design and operation. The current and future trend is likely to remain that of providing possible explanations to observed behaviour and suggesting the direction in which trials of new and modified gear might go.

8. AREAS OF FUTURE WORK

1. Short-term and long-term effect of intensive fishing on school size and distribution and attendant changes in behaviour of fish schools.

2. Differences in behaviour of schools of the same species but of different school size in relation to fishing gear.

3. Effect of meteorological changes and local hydrographic conditions on fish behaviour.

4. Influence of differential behaviour due to age, sex, reproductive state, feeding state and diel rhythm on catchability.

5. In regard to fish locomotion:

   (a) burst speeds and cruising speeds measured in the natural environment, as for example by sector-scanner, underwater observations by divers and underwater swimming speed apparatus

   (b) effect of escape reaction on subsequent swimming performance

   (c) direction and step length in escape from gear

   (d) developing a more adequate theory of fish locomotion, taking into account metabolic expenditure and hydrodynamic losses

6. Use of acoustic techniques to count fish immediately in front of gear, such as trawls or Danish seines.

7. Biological and non-biological sounds, which have produced favourable directional response in fishes should be employed in experimental fishing studies and further studies should be undertaken to evaluate the physical character and patterns of sounds that are most effective for this purpose. The reactions of tuna to sonar transmission are of particular interest.

8. The effect of ship noise; important in all fisheries, it is of pressing importance in the purse-seine fisheries.

9. For all stimuli to which fish are likely to be subjected, information is required on thresholds of behavioural responses in terms of $\triangle I/I$, where I is the initial stimulus strength and $\triangle I$ is the change in the strength of the stimulus just necessary to provide a response. Information is also required on the significance of the time component of a stimulus (e.g. rate of rise in relation to accommodation; duration in relation to adaptation) for behavioural responses. In addition, precise measurements of environmental variables related to response stimuli, both in the field and laboratory studies, are desired.

10. Reactions of fish to chemical substances, particularly from the point of view of developing artificial bait.

11. Observations on fish behaviour during the act of capture with divers, cameras, submersibles, sector scanners and other observational tools.

12. A combination of passive listening and echo sounding may allow certain targets to be identified. More information is required on the character of fish sounds and the incidence of sound production according to size, species and season.

13. The dominant sensory modalities employed by fish in the detection of gear should be determined.

14. More thorough comparative fishing experiments should be made to determine the effects of bridles (sweeps) on trawl catches and to elucidate their mode of action. In these experiments bioluminescence meters and hydrophones should be used.

15. The mapping of pressure fields and water-speed variations in front of and in and around fishing gear.

9 RECOMMENDATIONS

The participants of the Conference agreed that the following studies and experiments should be initiated or expanded beyond the present knowledge:

9.1 The Conference suggests that FAO consider the formation of a working party to recommend techniques and procedures for constructing an underwater laboratory and apparatus in order to measure behavioural and physiological responses in the natural environment. It is suggested the working party be comprised of laboratory experimentalists competent in the fields of behaviour and physiology and divers with knowledge and experience of submersibles and underwater diving technology.

9.2 The Conference stresses the special importance of investigations into schooling behaviour of fishes as the objective of commercial fisheries, consequently the Conference suggests that FAO consider the formation of a small working party of schooling behaviour experts, possibly convened aboard ship, to evaluate and study schooling in the natural environment.

9.3 The Conference suggests that FAO consider the formation of a working party to consider specific aspects of the theory and techniques of fish behavioural experimentation in relation to fishing techniques and tactics, with a view towards developing and disseminating through FAO a manual of procedure and analytical approaches to this problem.

10 CLOSING SESSION

The Chairman, Dr. D.L. Alverson, reviewed the scope and achievements of the Conference. This was followed by votes of thanks from Mr. S. Olsen on behalf of ICES, Mr. L.R. Day on behalf of ICNAF and Dr. A.R. Bayoumi on behalf of the participants of the Group Fellowship Study Tour, UN/FAO/USSR. Mr. W. Dickson, representing FAO and the Joint Scientific Secretaries, gave a closing speech. The Honorary President, Mr. K. Sunnanaa, emphasized the value of the Conference and declared it closed.

Appendix 1

A G E N D A

1 Opening of the Conference

2 Field observations on fish behaviour in important fisheries

3 Methods and techniques for studying fish behaviour in the natural environment

4 Experimental studies of fish reactions to physical and biological stimuli, both in the natural and in a controlled environment

5 Experimental studies of fish reactions to moving and fixed objects in order to clarify reactions to fishing gear

6 Application of observations and experiments on fish behaviour in designing fishing gear and devising tactics

7 Discussion and consideration of recommendations

8 Closing of the Conference

Appendix 2

OFFICERS OF THE CONFERENCE AND MEMBERS OF THE CONSULTATIVE GROUP

Honorary President	K. Sunnanaa	
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Convenors and Rapporteurs	Convenors	Rapporteurs
Field observations on fish behaviour in important fisheries	J.H.S. Blaxter	
a) Pelagic fish		E.L. Nakamura
b) Ground fish		S. Olsen
Methods and techniques for studying fish behaviour in the natural environment	D.H. Cushing	
a) Direct and indirect underwater observations		C.C. Hemmings
b) Sonic devices		L.S. Midttun
c) Comparative fishing		J.J. Foster
Experimental studies of fish reactions to physical and biological stimuli, both in the natural and in a controlled environment		
a) Non-biological stimuli	F.R. Harden Jones	S.B. Saila
b) Biological stimuli		
c) Learning and conditioning	G. Sundnes	E. Shaw
d) Fish locomotion		
Experimental studies of fish reactions to moving and fixed objects in order to clarify reactions to fishing gear	C. Nedelec	
a) Parts of gear and models in aquaria and at sea		F.W.H. Beamish
b) Full-scale gear		A.R. Margetts
c) Effect of fishing on escaping fish		
Applications of observations and experiments on fish behaviour in designing fishing gear and devising tactics	D.L. Alverson	E.J. de Boer

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*Members who did not participate at the Conference

Appendix 3

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1. Acoustical techniques for studying fish behaviour

Convenor: C.J. Chapman

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T. Sasaki
R.R. Villanueva
V. Valdez
D.A. Wickham

2. Uses of submersibles in marine research and fisheries

Convenor: T.B.S. Gorman

M.P. Aronov
J. Clark
C.C. Hemmings
O.N. Kiselev
V.N. Martyshevsky
T. Sasaki
R.B. Thompson

3. Possibilities of herding, aggregating and controlling and/or restricting movements of fish for the purpose of improving harvests, relevant to (a) extant gear (b) developing futuristic extractive processes

Convenor: J.J. Foster

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4. Experiments for behaviour studies and design of facilities

Convenor: J.M. Anderson

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S.B. Saila
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5. Short-term distribution patterns and fishing tactics and strategy

Convenor: A.P. Stickney

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6. Sensory physiology - its possible contribution to behaviour studies and to design of fishing gear

Convenor: C.C. Hemmings

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Appendix 5

ADDRESSES AT THE OPENING AND CLOSING SESSIONS

Opening address by Mr. K. Sunnanaa, Director-General of Fisheries, Bergen.

Honourable Guests, Ladies and Gentlemen:

It is my privilege, on behalf of the Norwegian Government and the Minister of Fisheries, to welcome you to this Conference.

Both the Norwegian Fisheries Authorities and especially myself as Director-General of Fisheries, were greatly pleased to receive the request from the Director-General of FAO to be hosts to this Conference. I would therefore be grateful if you, Dr. Holt, would convey my best thanks to the Director-General, Dr. Sen, for the honour and confidence he has shown to us.

Through the years, especially during the post-war period, many subjects bearing relation to the oceanography and fishing and processing industries have been discussed at many international meetings, and have been useful to research workers and fishery administrators.

In view of this it is indeed remarkable that one of the basic needs, namely the need for more knowledge about the behaviour of the fish when confronted by the fisherman and his gear, has not yet attracted the same international attention.

I will not try to go into the reasons for this. I might, however, draw your attention to the fact that the techniques and tactics used by the fishermen have, to a very great extent, been developed by the fishermen themselves on the basis of their experience. We have now reached the stage where fishing has developed into highly industrialized industries using rather complicated catching equipment of different kinds. The fishermen's own practical experience is no longer sufficient and it has not been so for years.

In addition, we have also seen that the highly effective methods invented by the technicians sometimes fail to fulfil the hopes that are placed in them, or else they prove so effective that they create new and very difficult problems.

The question may therefore be raised: Have the endeavours of all our experts been satisfactorily balanced ? It seems obvious that the biologists, so far, have not been able to give the inventors and the fishermen the necessary information about the reactions of the fish to the different new catching methods.

I have often also put the question to myself: How rational is our fishery? How much time and capital could we save if we knew more about fish behaviour?

If we had had more knowledge of these reactions, both of the fish as an individual and as a member of a shoal, I believe that the catching equipment would have developed more simply and directly towards more perfect methods of catching.

The purpose of the world-wide fishing activities is to supply food to the world population. Our task is to do this in the most rational way, one that will bring as large quantities of food as possible to consumers, using the best technical and economic methods and without decimating stocks of fish.

This cannot be done without close co-operation among all parties interested in the life that is in the sea, in the catching of fish and in the administration of the fisheries.

It is said in the Prospectus of this Conference that, when dealing with the question of fish behaviour, you intend to discuss more the tactics of fishing than its strategy.

I am administrator of the fisheries in a country where the fishing industry is of vital importance. This is one of the reasons why I also feel strongly about the global need for more quickly acquired knowledge about fish behaviour when using advanced fishing methods.

As a fishery administrator I have carried out many fishing experiments in order to test new inventions of fishing gear and equipment. The greater part of these experiments have been unsuccessful. But some experiments have been very successful, and they have caused me tremendous headaches and the greatest administrative difficulties, since they resulted in overfishing with disturbing effects on markets, and they also brought about all kinds of disturbances and protests and actions from groups in the industry, strongly supported in turn by groups of politicians.

In spite of this I will continue to spend money on such experiments because I like to do so; it is fun.

I hope that this Conference will do well when summarizing what you know about the relationship between fish behaviour and fishing techniques, when you are identifying the gaps in your knowledge, and when you are critically reviewing the prevailing methods and devices used to clarify this relationship. I hope that you will succeed when trying to advance further the application of the existing scientific data to efficient fishing methods. And to me it is most important that your discussions will encourage further research and experimental work in this field.

I am glad that you are holding your Conference here in Bergen with its centre for the fishery administration and the research institute, and which is also a town with old traditions as regards fishing, fish processing and trade in fishery products.

On behalf of the Norwegian Government and the Fishery Authorities, I should like to express the wish that this Conference will prove successful for FAO and all the participants, and consequently also for the fishing industries of all nations.

Opening address by Dr. S.J. Holt, Director of the Fishery Resources and Exploitation Division, Department of Fisheries, FAO, Rome.

Mr. President, Mr. Deputy Mayor, Ladies and Gentlemen:

It is my great pleasure to bring to this Conference the greetings and good wishes of the Director-General of the Food and Agriculture Organisation of the United Nations. The Assistant Director-General for Fisheries, Mr. Roy I. Jackson has also asked me to convey his greetings and express his regret that because of the proximity of the FAO General Conference he is unable to attend personally. We are indeed tremendously indebted to our hosts, the Government of Norway and the City of Bergen, for the excellent arrangements that have been made to provide the facilities that will help ensure the success of the Conference. We are deeply honoured, Mr.Sunnanaa, that you have accepted FAO's invitation to serve as Honorary President of the Conference, and most happy also to have with us, during this opening meeting, Mr. Ole Rieck, Acting Fylkesmann of the County of Bergen and Hordaland, and Mr. J. N. Bertnes representing the Ministry of Fisheries. Distinguished guests with us include the Principals of the University of Bergen and of the School of Economics and Business Administration, and the heads of the Norges Sildesalslag (the Herring Sales Organization) and of the State Fishery Bank. To all these gentlemen and Bodies I should like to extend the greetings of my Organization.

It is evident that our friends in the Directorate of Fisheries have put much effort into these preparations, and it is pleasant also to see here many familiar faces of our scientific colleagues from the Marine Fisheries Research Institute, including, I am glad to say, the Director of the Institute, Dr. Gunnar Rollefsen. Dr. Rollefsen has devoted much of his life to studies of fish behaviour and in providing facilities, as in the magnificent aquarium attached to his Institute here in Bergen, where such studies can better be pursued. It is thus particularly fitting that Bergen, an old fishing town and a leading centre of fisheries research, should be the place chosen for our Conference.

I should like to ask your patience while I say something about the reason that FAO has convened a world scientific and technical conference on this particular subject at this time. Our Department of Fisheries has the responsibility of carrying out, through the United Nations Development Programme, a large number of projects in less developed countries, for assisting them in the exploration and evaluation of fishery resources and in improving their methods of utilizing these resources. For this purpose we have working with us in various countries several hundred experts - mainly scientists and technicians - recruited almost entirely from the more advanced fishing countries, and I may say Norway is very high on the list of those who are assisting in this way. We are helping to create fishery research institutes in perhaps 30 countries and have built for these a large number of small and medium-sized research vessels. Some of the investigations being made under these projects are to provide a sound scientific - and especially biological - basis for the international management of fisheries, and this is increasingly our concern as marine resources everywhere become more intensively fished, and by more and more nations. We all hope that following the examples set in the northeastern and northwestern Atlantic and elsewhere it will be possible for countries to work together for conservation of resources, to ensure their future productivity so that all will benefit. While helping to strengthen the national basis of fishery research and administration in many of our 110 member countries, FAO is working, especially through its Intergovernmental Committee on Fisheries, to establish appropriate regional fishery councils and commissions with such objectives.

At the same time, however, we recognize the necessity for continually improving the efficiency of the fishing methods, gear and vessels. Fishing methods in use today have evolved from primitive methods. These primitive methods were frequently based on shrewd, if not strictly scientific observations of the behaviour patterns of fish, and gear were constructed to exploit those patterns. The changes in methods have been made by trial and error, sometimes quite rapidly in response to fundamental new developments in fishing practices, such as the introduction of power and of sonar.

More recently engineers have begun to study the hydrodynamic properties of some gear, particularly trawls, with a view to improving their mechanical efficiency by changes in design or handling. Unfortunately attempts to improve fishing gear or invent new gear on this basis have not always been successful. At the same time, biologists in many institutions have been pursuing basic research on fish behaviour, usually with no particular reference to the fishery problems. Now it seems to many of us that we may be approaching the point where fishing gear design becomes not an art or craft, but a science, at least in some respects. But this point can only be reached when we study fishing methods in relation on the one hand to the natural environment in which they operate and on the other hand to the behaviour of the animals they are intended to catch, both as individuals, and as social groups. This approach will require the cooperation and mutual understanding of many different kinds of specialists. Those who can contribute range from the field naturalist and the experimental biologist to the mechanical and electronics engineers and the fishermen themselves.

The relevant studies and activities include the observation of fishes in nature, using all conceivable kinds of instruments, sensors and underwater facilities; experimental studies in aquaria of individual and group reactions to natural and artificial stimuli; physiological research; acoustics; hydrodynamics and investigation of materials, even mathematics and statistics, oceanography and the psychology of learning. Thus these fundamental scientific activities can lead to highly practical ends, either directly or indirectly, soon or in the long run, but, we believe, inevitably.

It is therefore the purpose of this Conference to encourage the meeting together of scientists and technical people not only from different parts of the world, but also from different disciplines in the hope that better understanding will emerge from the cross-fertilization achieved and that guides will be formulated for the magnitude and the direction of the research needed in future. We hope too, of course, that there could be some immediate practical results in seeing how, taking full account of experience so far, existing fishing methods can be adopted to the new situations in which they are being tried out. All that I have said about fishing gear and equipment can be taken to apply also, I think, to the tactics of fishing - that is to the finding of fish and the deployment of fleets.

Specialists from more than 30 countries are here today and over 60 scientific papers have been written for the Conference. Participants include 11 from developing countries who, with instructors and FAO staff, have just returned from an extensive study tour in the Soviet Union which was devoted to the same subject as this Conference. In this joint FAO/USSR project, as in previous ones, visits were made to centres of research and of fishing industry, lectures were given by Russian scientists and by scientists from other leading countries, and seminars were held. During their stay in Bergen the participants will be the guests of the Norwegian Agency for International Development, and our deepest thanks are due to that Agency without whose assistance several younger scientists might not have been able to attend, to contribute to and benefit from, the discussions we shall have during the next 10 days.

Everyone here at this Conference is present in his individual capacity; there are no official delegations and we do not expect the discussions to lead to formal resolutions or decisions. There will, we hope, be much exchange of ideas, some criticism, a number of recommendations for further research and, if necessary, action by FAO. It will be the task of the Chairman of the Conference to ensure these results, and Dr. Lee Alverson, of the United States Bureau of Commercial Fisheries, has kindly accepted FAO's invitation to the task. Dr. Alverson is, of course, well known to most of you here, especially for the scientific approach of himself and his colleagues in Seattle to fishery exploitation and gear research. He too has just returned as a consultant to FAO, from the Study Tour. Dr. Ivan Nikonorov of the Ministry of Fisheries, Moscow, and Professor Tadayoshi Sasaki, of the Tokyo University of Fisheries, have graciously accepted the offices of Vice-Chairman.

In addition, we have been lucky enough to have the advice, in the preparations for this Conference, of several specialists who formed a Consultative Group, and many of these have, perhaps rashly, accepted to act as Convenors for the various sections.

This has, I am afraid, been a rather long introduction but I hope it will nevertheless have been useful to those of you who have not previously been associated with FAO conferences.

May I again thank all our hosts for making this one possible.

Closing address by Dr. D.L. Alverson, Chairman of the Conference

Mr. Sunnanaa, Ladies and Gentlemen:

The FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics provided the participants the unique opportunity to investigate how physical, chemical and biological factors govern the efficiency of fishing systems.

The Conference presented scientific and technical papers which consider fishes' sensory capabilities, swimming speeds, direction responses to fishing gear, vertical and horizontal short-term movements, the general behaviour to various chemical and physical stimuli, and investigational techniques.

The application of information on the behaviour of fishes can play an important role in (1) increasing the yield in weight or value from existing fisheries while maintaining or reducing production cost and (2) extending harvest capabilities to new zones of the ocean and to species not now utilised. There will obviously be those who will question the wisdom of increasing harvest efficiency, particularly for those fisheries which are under heavy exploitation and which are considered to be yielding catches at or beyond their maximum sustainable yield level. If we critically examine this problem we will see that improvement can adequately adjust for changes in efficiency and it is not efficiency we must concern ourselves with as much as our inability to effectively apply at a national and international level conservation tools already at our disposal. Quite independent of the problems of management there is at times a need to initiate technological changes in used resources to maintain the economic and physical yields of fisheries. As standards of living are improved, production cost will rise and, if there are no compensatory technological improvements, it is possible that these costs will eventually exceed those that we can reasonably expect man to pay; hence the resource will be lost from the food stream.

Technological change is the most important means by which we can hope to utilize effectively the biological potential of the oceans. This potential, even when considering the size and types of fish we now use, is estimated to be 2 to 5 fold of the present world catch, and if one considers the variety of unusual species and harvesting farms somewhat lower in the food chain the potential harvest is much greater. There is no attempt here to establish what this potential might be but to emphasize that its utilization will require more sophisticated extraction processes than are now available.

The chances for improving the harvest of the ocean living resources lies in altering existing methods and developing new harvest modes. If we work within the framework of the existing fishing system we may:

1. Alter the search and detection phase.

2. Alter the tactics of shooting, setting and hauling gear (how it is deployed).

3. Alter and develop new devices for capturing fish.

In considering the above there are perhaps two main factors governing the efficiency of present harvest systems. Assuming that we might lump tactics and gear as an integral step and that they are not mutually exclusive, then the probability that we will catch those fish that come within the influence of the gear and the probability that commercial concentrations will be located in a specific period may be considered coefficients governing efficiency of capture. The time allowed for searching and actual phases of fishing are important factors to consider when evaluating the potential change that might be made to alter either of these coefficients.

From an engineering standpoint we could use knowledge of fish behaviour to alter the search strategy, to develop more efficient detection devices, or to redesign the extant gear to increase the probability of capture. We also have the opportunity of preventing fish behaviour that leads to escape by electro-narcosis, and by other physical or perhaps chemical means increasing the probability of capturing those fish which come under the gear's influence. Finally we may use knowledge of how fish behave to certain stimuli to herd, lead or change its location to one that is more favourable for harvest. This possibility has been demonstrated by some responses fish have shown to acoustic stimuli. This field perhaps offers one of the unique opportunities for men not only to prevent escape of fish from existing gear but to increase the density of fish within their path or area of influence.

Although this Conference has essentially involved itself with the behaviour of fish as related to fishing techniques and tactics we should not overlook the possibilities that knowledge of fish behaviour has wider application which will benefit the field of applied fisheries science. We may eventually use such knowledge to improve marine resources, to develop the opportunity for successful fish farming activities and to secure more effectively the maximum sustainable yield of the various resources exploited with greater knowledge of all aspects of fish behaviour applicable to methods and tactics.

Closing address by Mr. W. Dickson, Scientific Secretary of the Conference

Mr. Sunnanaa, Ladies and Gentlemen:

When this Conference was first mooted, it was argued by some that it would be an effort to spin it out to eight working days. As it has turned out, with hectic activity inside the conference room itself and in the back rooms, it has been difficult to squeeze it into eight days. The girls back there have been managing a veritable paper mill. On behalf of FAO, I would like to thank Mr. Angerman and all the Norwegian secretariat who have so competently made preparations for the Conference and helped us to carry it out. Between the Norwegian secretariat and the staff of the Marine Fisheries Research Institute we have all made or renewed many friendships. I would like now to thank Dr. Hollefsen and all of his staff who have shown such great interest and done such stalwart work in and for this Conference.

As our work here draws to a close, I should inform you of the next steps that have to be taken in producing the proceedings of the Conference. We intend to publish the Conference proceedings in two or perhaps three volumes. The first volume will be produced in the three languages of FAO. It will include the list of participants, the list of papers and the abstracts* of these papers. It will also cover the opening session, the Chairman and Secretaries' reports, the reports of the Convenors covering the five agenda items, the reports and suggestions of the six working parties, suggestions for future areas of work and the recommendation that FAO consider the establishment of certain working groups.

The papers, in the language in which they were submitted, will be collected in Volume 2 which quite likely will have to be extended into Volume 3. Each author will receive a copy of these volumes. The Secretaries promise to see this work done as soon as possible. The majority of authors have managed to attend the Conference and consequently the Conference discussions have been the more fruitful. Most authors present have handed in to the Secretariat an updated version of their paper. Authors who have not managed to attend have already been sent copies of their paper, with the request that a final version be returned to us by 30 November. This will be the deadline after which papers will be produced in the final proceedings as they now stand, if corrections are not received by that date.

Having said that, we would like to say in milder tone: thank you to all the authors. This has been a serious Conference where research workers trained in different disciplines and with widely different experiences with fish and fisheries have built up a new respect for each other. I say new deliberately: it was one of FAO's intentions that this Conference should do just this. It was a risky thing we planned, when you think about it, for if this new respect for each other, in interests as far apart as fishing gear technology and sensory physiology, had not been built up, then the Conference would have failed. It has not failed, even if the going has not always been easy.

Another reason for our success has been our good choice of a Chairman. There must be few people with the breadth of view to guide a conference of this sort. On behalf of FAO I would like to thank Dr. Alverson for what he has done.

The Joint Secretaries would also like to thank the Consultative Group for the guidance they have given us before and during the Conference. Thank you also to the Convenors and Rapporteurs and Convenors of Working Parties. All have had a tough job to do, with little time in which to write their reports. Thank you to all the participants for the enthusiasm you have shown.

Finally, we are not disappointed that Bergen was the seat of the Conference for even though the weather has been awful the welcome has been tremendous.

*Abstracts will appear in Volume 2

Appendix 6

AUTHOR INDEX AND TITLES OF PAPERS

Author	Title	No. and Category Review (R) Experience(E)	Original Language
Alverson, D.L.	Distribution and behaviour of Pacific hake as related to design of fishing strategy and harvest rationale	E/11	En.
Aronov, M.P. and B.V. Vyskrebentzev	Underwater observations on the behaviour of fishes in the zone of trawling	E/53	En.
Beamish, F.W.H.	Photographic observations on reactions of fish ahead of otter trawls	E/25	En.
Blaxter, J.H.S.	Swimming speeds of fish	R/3	En.
Brandt, A.von	Application of observations on fish behaviour for fishing methods and gear construction	R/8	En.
Bridger, J.P.	Behaviour of demersal fish in the path of a trawl	E/41	En.
Chapman, C.J. and A.D. Hawkins	The importance of sound in fish behaviour in relation to capture by trawls	E/42	En.
Christensen, J.M.	A rake trawl designed for catching young soles	E/32	En.
Cushing, D.H.	The use of echo sounders and scanners in the study of fish behaviour	R/5	En.
Daniulyté, G. and G. Malukina	The reaction of some fishes in an electric field	E/44	En.
Devold, F.	The behaviour of the Norwegian tribe of the Atlanto-Scandian herring	E/27	En.
Dowd, R.G.	An echo counting system for demersal fishes	E/7	En.
Dragesund, O. and L.S. Midttun	Preliminary results from the fishery research survey of West African waters *	E/24	En.
Enger, P.S.	Sound reception in teleost fishes in relation to the sound source distance	E/1	En.
Foster, J.J.	The influence of fish behaviour on trawl design with special reference to mathematical interpretations of observations on the swimming speeds of fish and results of C.F. experiments	E/43	En.

* Abstract only

Author	Title	No. and Category	Original Language
Gauthier, M.	Pêche avec lampes immergées pratiquée dans le Golfe Saint-Laurent	E/28	Fr.
Groot, S.J. de	A review paper on the behaviour of flatfishes	R/7	En.
Hamashima, K., I. Mori and Y. Kuwano	Some observations on fish schools and their environment	E/18	En.
Harden Jones, F.R.	Observations on the behaviour of fish made with the bifocal sector scanner	E/37	En.
Hemmings, C.C.	Observations on the behaviour of fish during capture by the Danish seine net, and their relation to herding by trawl bridles	E/35	En.
Hemmings, C.C.	A discussion of the principles of observing fish behaviour in relation to fishing gear	E/36	En.
High, W.L.	Scuba diving, a valuable tool for investigating the behaviour of fish within the influence of fishing gear	E/2	En.
Inoue, M. and T. Ayodhyoa	Direction of setting the purse seine in consideration of the behaviour of anchovy schools	E/31	En.
Iverson, R.T.B.	Auditory thresholds of the scombrid fish Euthynnus affinis, with comments on the use of sound in tuna fishing	E/54	En.
Kawamoto, N.	Fish behaviour in relation to variation in osmotic pressures	E/21	En.
Kurc, G.	L'application à la pêche des réactions phototropiques des poissons	E/4	Fr.
Kurc, G.	Un chalut conçu en fonction du comportement des crevettes	E/5	Fr.
Kuroki, T.	Problems of designing fishing gear as related to behaviour of fish	E/26	En.
Lestev, A.V.	Some peculiarities of trawling technique applied in fishing for Bering Sea redfish depending on its behaviour and environment	E/49	En.
Magnusson, J.J.	Swimming activity of the scombrid fish Euthynnus affinis as related to search for food	E/17	En.

Author	Title	No. and Category	Original Language
Manteifel, B.P., I.V. Nikonorov, D.V. Radakov and A.I. Treschev	Main trends and some results of fish behaviour studies in the U.S.S.R.	E/48	En.
Margetts, A.R.	Comparative and experimental fishing as methods for studying fish behaviour in the natural environment	R/6	En.
Margetts, A.R.	Catching clupeoid fish by pelagic trawl	E/23	En.
Martyshevsky, V.N. and V.K. Korotkov	Fish behaviour in the area of the trawl, as studied by bathyplane	E/45	En.
Mohr, H.	Detection of fish and observation of fish behaviour by echo analysis and passive listening	R/4	En.
Mohr, H.	Observations on the Atlanto-Scandian herring with respect to schooling and reactions to fishing gear	E/29	En.
Muzinić, R.	Observations on the reactions of the sardine (Sardina pilchardus Walb.) to intermittent white light	E/55	En.
Nakamura, E.L.	A review of field observations on tuna behaviour	R/2	En.
Nakamura, E.L.	Visual acuity of yellowfin tuna, Thunnus albacares	E/19	En.
Nedelec, C. and M. Portier	Influence du taux d'armement sur la vitesse plongée de la senne	E/6	Fr.
Nelson, M.O.	Availability of Pacific hake (Merluccius productus) related to the harvesting process	E/34	En.
Nikonorov, I.V.	Behaviour of fishes in the zone of the light trace during pumping fishery	E/51	En.
Nomura, M.	Behaviour of fish against driftnets and trapnets	E/40	En.
Okonski, S.	Echo sounding observations of fish behaviour in the proximity of the trawl	E/12	En.
Okonski, S.	The influence of fish behaviour on the choice of the trawl net shape and size	E/13	En.
Olsen, K.	A comparison of acoustic threshold in cod with recordings of ship-noise	E/16	En.

Author	Title	No. and Category	Original Language
Parrish, B.B.	A review of some experimental studies of fish reactions to stationary and moving objects of relevance to fish capture processes	R/12	En.
Parrish, B.B., J.H.S. Blaxter, J.A. Pope and R.H. Osborn	Underwater photography of fish behaviour in response to trawls	E/56	En.
Pavlov, D.S.	The optomotor reaction of fishes	E/47	En.
Poddubny, A.G.	Sonic tags and floats as a means of studying fish response to natural environmental changes and to fishing gears	E/46	En.
Ponomarenko, V.P.	On the negative response of Polar cod (Boreogadus saida Lepechin) to electric lights	E/50	En.
Radakov, D.V.	The biological and practical importance of schooling behaviour in fishes	E/52	En.
Rollefsen, G.	Big events on a small scale	E/10	En.
Saila, S.B.	Some applications of observations and experiments on fish behaviour in designing fishing gear and devising tactics, with suggestions for future studies	R/1	En.
Saila, S.B. and J.M. Flowers	Elementary applications of search theory to fishing tactics as related to some aspects of fish behaviour	E/9	En.
Saetersdal, G.	Review of information on the behaviour of gadoid fish	R/10	En.
Sasaki, T.	Methods and techniques for studying fish behaviour in their natural environment	R/9	En.
Shaw, E.	Some new thoughts on the schooling of fishes	R/11	En.
Shiokawa, T.	Studying of the swimming habits of flying fish in the spawning season	E/30	En.
Stickney, A.P.	Orientation of juvenile Atlantic herring (Clupea harengus harengus L.) to temperature and salinity	E/8	En.
Strom, P.	Philippine purse seining with light attraction	E/39	En.
Tyler, J.E.	The natural light field underwater	E/22	En.

Author	Title	No. and Category	Original Language
Verheijen, F.J.	Some aspects of the reactivity of fish to visual stimuli in the natural and in a controlled environment	E/15	En.
Yuen, H.S.H.	Response of skipjack tuna (Katsuwonus pelamis) to experimental changes in pole-and-line fishing operations	E/33	En.
Zei, M.	The behaviour of Sardinella aurita Val., in relation to light and temperature	E/20	En.
Zijlstra, J.J.	On the escapement of fish through the upper part of a herring trawl	E/38	En.
Zupanovic, S.	Study of sardine (Sardina pilchardus Walb.) behaviour in their natural environment by echo sounder and environmental factors	E/3	En.
Zupanovic, S.	Behaviour of hake (Merluccius merluccius L.) in relation to trawls with wire cable bridles	E/14	En.

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